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THE BIOCHEMICAL, PHYSIOLOGICAL, AND METABOLIC EVALUATION OF HUMAN SUBJECTS IN A LIFE SUPPORT SYSTEMS EVALUATOR AND ON A DIET OF PRECOOKED FREEZE DEHYDRATED FOODS

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JOINT NASA/USAF STUDY

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AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

NOTICES

The voluntary informed consent of the subjects used in this research was obtained as required by Air Force Regulation 169-8.

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FOREWORD

This research was initiated by the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, and was accomplished by the Department of Research of the Miami Valley Hospital, Dayton, Ohio, and the Biotechnology Branch, Life Support Division, Biomedical Laboratory, Aerospace Medical Research Laboratories. This effort was supported jointly by the USAF under Project No. 7164, "Biomedical Criteria for Aerospace Flight," Task No. 716405, "Aerospace Nutrition," and NASA Manned Spacecraft Center, Houston, Texas, under Defense Purchase Request R-85, "The Protein, Water, and Energy Requirements of Man Under Simulated Aerospace Conditions." This contract was initiated by 1st Lt John E. Vanderveen, monitored by 1st Lt Keith J. Smith, and completed by Alton E. Prince, PhD, for the USAF. Technical contract monitor for NASA was Paul A. Lachance, PhD. The research effort of the Department of Research of the Miami Valley Hospital, was accomplished under Contract AF 33 (657) - 11716. Bernard J. Katchman, PhD, and George M. Homer, PhD, were technical contract administrators, and Robert E. Zipf, MD, Director of Research, had overall contractual responsibility.

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This technical report has been reviewed and is approved.

WAYNE H. McCANDLESS
Technical Director
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ABSTRACT

A 6-week study with four college students as volunteer subjects was conducted for the purpose of evaluating the water, caloric, and protein requirements of individuals undergoing stresses imposed by simulated aerospace conditions. The subjects were confined in a controlled activity facility for 2 weeks and in the Life Support Systems Evaluator for 4 weeks during which time they wore an unpressurized MA-10 pressure suit 8 hours each day for 14 consecutive days. A 3-day cycle diet of precooked freeze dehydrated foods was served at room temperature and was comprised of about 105 g of protein, 328 g of carbohydrate, 89 g of fat, and 2600 kcal per day. The daily requirement of water was 2200 ml per man day of which 700 ml were consumed ad libitum. The diet was highly acceptable and efficiently utilized. Only minimal body weight changes were observed. The nutrient intake of the diet was adequate in that a 70 kg man was maintained without any weight loss. Metabolic balances show excellent adjustment to the diet; all subjects were in positive balance for nitrogen and for the major inorganic constituents. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal ranges and no significant differences were observed due to confinement in the Life Support Systems Evaluator. All subjects maintained excellent health throughout all the test periods.

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SECTION I

INTRODUCTION

A series of studies have been designed to establish the water, energy, and protein as well as hygienic requirements of man under simulated aerospace conditions. Four untrained subjects, carefully selected after extensive medical, dental, and psychiatric examinations, were used in each 6-week study. Baseline data were obtained in a controlled activity facility (CAF)* and aerospace conditions were simulated by use of unpressurized MA-10 pressure suits,** and the Life Support Systems Evaluator (LSSE)*. The subjects ate diets of fresh foods and diets of experimental aerospace foods.

The results thus far (1,2,3) show that there are no significant changes in the water, energy, and protein requirements of man in confinement in the CAF, or in the CAF when wearing the MA-10 pressure suit, and while eating a diet composed of fresh foods or precooked freeze dehydrated foods. There were no significant changes while in the LSSE when wearing the MA-10 pressure suit and on a diet composed of fresh foods. Normal health was maintained throughout these experiments. Food acceptability was high for the fresh foods when served at their usual temperature; fresh foods were less acceptable when served at room temperature (3).

This study deals with the evaluation of the water, energy, and protein requirements of four subjects who were confined in the LSSE for 4 weeks while eating a diet composed of precooked freeze dehydrated foods. The initial phase of this study consisted of a 1-week confinement and orientation period while in the CAF. A 4-week confinement in the LSSE followed wherein the subjects participated in activities of simulated space travel, in the collection of biological samples, and in making requisite physiological measurements. Specific evaluations of energy, nitrogen, fat, crude fiber, and electrolyte requirements with respect to metabolic balance and digestibility of these foodstuffs were accomplished. The general health of the subjects was followed during the various phases of the study. In addition to an evaluation of the physiological adequacy, an organoleptic acceptability rating of the diet was carried out by the subjects.

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* The controlled activity facility (CAF) and the Life Support Systems Evaluator (LSSE) at the Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, were used to provide a simulated space cabin environment.

** The MA-10 pressure suits were furnished for these experiments by the Manned Spacecraft Center, NASA, Houston, Texas.

SECTION II

METHODS

Four human male subjects were confined either in the CAF or the LSSE for a period of 6 weeks. Each of the subjects was selected upon the basis of medical, dental, psychiatric, and microbiological examinations. The physical characteristics of the subjects are listed in table I.

TABLE I

PHYSICAL CHARACTERISTICS OF TEST SUBJECTS

Subject No.	Age	Weight		Height	
		kg	lb	cm	in
21	21	59.1	130	170	67
22	22	70.5	155	178	70
23	24	79.5	175	173	68
24	22	83.2	183	170	67

The subjects were confined in the CAF during the first and sixth weeks and in the LSSE during the middle 4 weeks of the 6-week study. The experimental design and daily activity schedule are presented in tables II and III, respectively. The protocol for the CAF and LSSE was such that additional stress of confinement was imposed by the LSSE. Only a limited number of personnel were permitted to enter the CAF during the first and sixth weeks; no personnel were permitted to enter the LSSE. Communications were conducted by two-way telephone in the CAF, and by telephone and television while in the LSSE. The subjects were monitored 24 hours a day and were examined daily by a physician while in the CAF and were interviewed via telephone by a physician each day while in the LSSE.

TABLE II

EXPERIMENTAL DESIGN

Experimental day	Condition (period)	Metabolic diet	Blood collection	Urine	Feces
1	Pre-Chamber	1			
2		2			
3	7 days	3	X	U 1	F 1
4		1			
5		2			
6		3	X	U 2	F 2
7		1			
8	Chamber	2			
9		3			
10	28 days	1		U 3	
11		2			
12		3	X		F 3
13		1		U 4	
14		2			
15		3			
16		1		U 5	
17		2			
18		3	X		F 4
19		1		U 6	
20		2			
21		3			
22		1		U 7	
23		2			
24		3	X		
25		1		U 8	F 5
26		2			
27		3			
28		1		U 9	
29		2			
30		3			
31		1		U 10	
32		2			
33		3	X		F 6
34		1		U 11	
35		2			
36	Post-Chamber	3			
37		1			
38	7 days	2		U 12	F 7
39		3	X		
40		1			
41		2		U 13	F 8
42		3			
43			X		

TABLE III

DAILY ACTIVITY SCHEDULE

Time	Subject No. 21 / 22	Subject No. 23 / 24	Time
0730	Wake; void; physiological measurements. Transfer food and other items into chamber. Biological specimens collected and returned to laboratory.		0730
0900	Eat meal A		0900
1000	Don MA-10 pressure suit	Sleep	1000
1100	Psychological testing 22		1100
1200	Exercise 21		1200
1300	Eat meal B		1300
1400	Psychological testing 21		1400
1500	Exercise 22		1500
1600	Free time and baralyme transfer		1600
1700	Eat meal C		1700
1800	Free time and exercise		1800
1900			1900
2000			2000
2100	Eat meal D	Eat meal B	2100
2200	Free time		2200
2300		Don MA-10 pressure suit	2300
2400	Sleep	Free time	2400
0100		Eat meal C	0100
0200		Free time	0200
0300		Psychological testing 24	0300
0400		Exercise 23	0400
0500		Eat meal D	0500
0600		Psychological testing 23	0600
0700		Exercise 24	0700
0730			0730

Every effort was made to eliminate the accidental introduction of contaminating microorganisms into the subjects' living areas. Those persons entering the CAF were always required to scrub and don sterile cap, gown, gloves, and shoe coverings. Subjects were thoroughly showered and scrubbed with a bactericide followed by a rinse with 70% alcohol prior to donning sterile clothing and entering either the CAF or the LSSE. During the entire study, swabs were made of specific body areas, environmental areas, and fecal samples for the purpose of evaluating the microbiological flora existing under the prevailing experimental conditions. These results will be reported separately.

No shaving, haircuts or hair grooming, or clipping of nails were permitted during the experiment. Oral hygiene was limited to the use of an electric toothbrush and gum stimulator for the first week, and a toothbrush and water only during the remaining 5 weeks of the study.

Requisite chemical analyses were accomplished as follows: food - moisture (4), nitrogen (5), fat (6), crude fiber (7), ash (8), sodium and potassium (9), chloride (10), calcium and magnesium (11), phosphorus (12), calorimetry (13), and carbohydrate determined by difference; blood - Schilling differential, white blood cell count, red blood cell count, total eosinophil, platelet, and reticulocyte counts, hematocrit (14), hemoglobin (15), glucose (16), creatinine (17), total protein, albumin and A/G ratio (18), alpha-amino nitrogen (19), serum acid and alkaline phosphatases (20), serum glutamic oxalacetic transaminase and serum glutamic pyruvic transaminase (21), calcium (22), chloride (23), phosphorus (24), and sodium and potassium (25); urine - daily volume, moisture, and total solids content (26), specific gravity (27), *p*H (28), qualitative protein (29), creatinine and creatine (30), 17-ketosteroids and 17-hydroxycorticoids (31), nitrogen (5), sodium and potassium (9), chloride (10), calcium and magnesium (11), phosphorus (12), and calorimetry (13); feces - moisture (4), nitrogen (5), fat (6), crude fiber (7), ash (8), sodium and potassium (9), chloride (10), calcium and magnesium (11), calorimetry (13), and occult blood on selected samples.

Sample collections were made as designated in table II. Food samples were collected during the first, third, and fifth weeks of the experiment and analyzed. Fasting venous blood samples were drawn for hematology and chemical analyses. Urine samples were collected daily and the requisite analyses made prior to dilution of the 24-hour volume to 2 liters and combination of 3-day aliquots for further analyses. Fecal samples were frozen as received and combined before analyses.

The total fecal and urinary outputs and the mean daily outputs of various nutrient food analyses were utilized for the calculation of nutrient digestibilities and balances. The balances were computed by subtracting the total output of a given constituent excreted in the urine and feces from the total dietary intake of that constituent. The coefficients of apparent digestibility were calculated by subtracting the fecal excretion from the dietary intake and determing the percent of total intake absorbed or utilized.

Physiological measurements were as follows: water intake, oral temperature, body weight, blood pressure, and heart rate. Heart rate measurements were made at the same time (0800) on all subjects under conditions of normal rest. Additional heart rate measurements were made on all subjects at different times while undergoing the following specified exercise prodecure: rest 10 minutes, measure heart rate; exercise 10 minutes on an ergometer, measure heart rate; and rest 10 minutes, measure heart rate. The work load chosen for the subjects on the ergometer was established to require an approximate expenditure of 300 kcal per hour.

The metabolic diet consisted of a 3-day cycle diet of precooked freeze dehydrated foods served at room temperature. The compositions of the metabolic diets are presented in tables IV through VI where the average calculated values (32) are as follows: 327.6 g of carbohydrate, 104.7 g of protein, 89.3 g of fat, and 2600 kcal per day. Diet 1 was supplemented with 0.472 g of calcium and diet 2 with 0.157 g of calcium in order to bring the daily calcium intake up to that in diet 3. In addition to adjusting the diet composition so that daily food intakes were comparable (carbohydrate, protein, fat, and calories), the four daily meals were similarly adjusted within each day's diet and for the same meal served on separate days. The actual chemical analyses of the metabolic diets are presented in table VII. This diet was matched to a fresh food diet of a previous study (3) and food selected to eliminate items rated low in a previous study (2).

All food items were prepared within a 24-hour period prior to serving according to instructions establishee by the dietitian. All items were prepared with distilled water. Individual portions for each meal were weighed to the nearest gram in preweighed and treated paper containers. The containers were labeled with the date and the appropriate subject, diet, and meal number, and stored in a refrigerator. A complete day's supply of food for the four subjects was transferred to either the CAF or the LSSE between 0800 and 0900 daily. The subjects were instructed to retain all food in the refrigerator; each meal was removed one-half hour prior to the scheduled meal hour so that the food was consumed at room temperature.

The subjects were instructed on the importance of consuming all food provided at each meal. The subjects were also instructed to notify the physiological monitor in the event that any illness occurred which necessitated reweighing of food.

The method of food evaluation in terms of a nine-point acceptability scale used in previous experiments (1, 2, 3) was followed for this study. The form shown in table VIII was presented to each subject at each meal with the requirement that all food items be rated according to the given scale of acceptability. Additional comments regarding food preparations, food combinations, monotony, etc., were encouraged.

TABLE IV

METABOLIC DIET 1

	Weight g	Carbohydrate g	Protein g	Fat g
Meal A				
Apricot cereal	37.0	25.5	3.1	6.1
Apple juice	180.0	25.2	0.1	Trace
Sausage	124.0	2.8	20.9	13.1
Cinnamon toast	11.4	7.0	1.1	2.8
Fruit cocktail	106.0	20.5	0.6	Trace
	458.4	81.0	25.8	22.0
Meal B				
Toast bread cubes	35.5	20.1	5.3	7.4
Chicken and gravy	109.0	8.6	12.6	1.1
Pineapple cubes	35.0	20.9	4.1	8.4
Cocoa	182.0	31.8	3.1	5.1
	361.5	81.4	25.1	22.0
Meal C				
Toast	23.8	11.9	4.0	6.8
Tuna salad	79.5	3.3	19.5	11.6
Apricot pudding	182.0	61.4	1.3	4.9
Tea	148.0	7.7	0.1	Trace
	433.3	84.3	24.9	23.3
Meal D				
Beef and vegetables	109.5	6.9	14.3	2.0
Orange-grapefruit juice	175.0	18.8	1.2	Trace
Potato salad	81.5	8.1	6.0	9.8
Toast	9.5	4.7	1.6	2.7
Date fruitcake	66.9	42.3	2.9	8.1
	442.4	80.8	26.0	22.6
Daily total	1695.6	327.5	101.8	89.9
Total calories	2602			

Calculated values.

TABLE V

METABOLIC DIET 2

	Weight g	Carbohydrate g	Protein g	Fat g
Meal A				
Pineapple juice	182.0	26.5	0.6	Trace
All Star cereal	108.0	18.7	3.5	0.2
Bacon and egg bites	26.0	1.1	8.9	15.0
Beef sandwich	16.8	3.6	9.5	2.5
Cocoa	182.0	31.8	3.1	5.1
	514.8	81.7	25.6	22.8
Meal B				
Beef bites	24.5	3.0	15.6	0.6
Potato salad	81.5	8.1	6.0	9.8
Toast	12.7	6.3	2.1	3.6
Chocolate pudding	182.0	54.7	2.7	9.2
Tea	148.0	7.7	0.1	Trace
	448.7	79.8	26.5	23.2
Meal C				
Grapefruit juice	175.0	18.9	1.0	Trace
Chicken bites	28.5	1.7	17.7	6.2
Potato chip blocks	32.3	25.9	2.7	1.2
Peaches	104.0	17.9	1.0	Trace
Brownies	38.8	18.0	3.0	14.8
	378.6	82.4	25.4	22.2
Meal D				
Potato soup	189.0	34.3	8.2	8.2
Shrimp cocktail	86.0	9.6	15.9	1.6
Toast bread cubes	53.3	30.2	8.0	11.2
Tea	148.0	7.7	0.1	Trace
	476.3	81.8	32.2	21.0
Daily total	1818.4	325.7	109.7	89.2
Total calories	2594			

Calculated values.

TABLE VI

METABOLIC DIET 3

	Weight g	Carbohydrate g	Protein g	Fat g
Meal A				
Orange pineapple juice	178.0	23.1	1.0	Trace
Sugar Frosted Flakes	120.8	31.3	3.4	0.1
Bacon squares	15.0	1.9	7.9	3.5
Peanut butter sandwich	34.4	10.2	10.8	11.8
Apricot cubes	28.4	16.4	3.5	7.3
	376.6	82.9	26.6	22.7
Meal B				
Salmon salad	123.0	0.7	19.2	16.6
Potato chip blocks	32.3	25.9	2.7	1.2
Apple sauce	168.0	40.5	0.3	0.2
Pound cake	18.1	9.8	1.5	5.0
Tea	148.0	7.7	0.1	Trace
	489.4	84.6	23.8	23.0
Meal C				
Grape juice	181.0	25.7	0.5	Trace
Chicken and vegetables	109.0	3.7	17.6	1.4
Toast	19.0	9.4	3.2	5.4
Pineapple fruit cake	78.8	44.3	5.0	15.4
	387.8	83.1	26.3	22.2
Meal D				
Spaghetti and meat	105.0	6.2	9.9	2.9
Cheese sandwich	33.8	6.8	15.0	10.1
Butterscotch pudding	182.0	58.2	1.2	7.8
Tea	148.0	7.7	0.1	Trace
	468.8	78.9	26.2	20.8
Daily total	1722.6	329.5	102.9	88.7
Total calories	2603			

Calculated values.

TABLE VII

ANALYSIS OF PRECOOKED, FREEZE DEHYDRATED METABOLIC DIETS

Constituent	Metabolic diet 1	Metabolic diet 2	Metabolic diet 3
		g/24 hr	
Weight	1730	1790	1640
Dry weight	524	522	512
Water	1206	1268	1128
Nitrogen	19.29	19.13	17.12
Protein	120.5	119.6	107.0
Fat	90.0	89.4	89.2
Cellulose	6.1	7.2	5.7
Carbohydrate*	272.9	277.6	289.6
Calcium**	0.910	0.856	0.899
Phosphorus	1.39	1.60	1.47
Sodium	4.80	4.77	4.45
Potassium	3.26	3.75	2.84
Chloride†	7.07	6.20	6.54
Magnesium	0.305	0.344	0.282

Analyses by Wisconsin Alumni Research Foundation, Madison, Wis.

* Calculated by difference.

** 0.472 and 0.157 g added as supplements to metabolic diets 1 and 2, respectively.

† As sodium chloride.

TABLE VIII

MEAL EVALUATION FORM

Pre-cooked, freeze dehydrated diet   Diet ______ Meal ______

Name ________________________________ Date ______________

Rate each item with the number that best indicates your taste

9 - Like Extremely
8 - Like Very Much
7 - Like Moderately
6 - Like Slightly
5 - Neither Like Nor Dislike
4 - Dislike Slightly
3 - Dislike Moderately
2 - Dislike Very Much
1 - Dislike Extremely

Meal A	Score	Meal B	Score
Apple juice	______	Chicken and gravy	______
Apricot cereal	______	Toast bread cubes	______
Sausage	______	Pineapple cubes	______
Cinnamon toast	______	Cocoa	______
Fruit cocktail	______		
Meal C		**Meal D**	
Tuna salad	______	Orange-grapefruit juice	______
Toast	______	Beef and vegetables	______
Apricot pudding	______	Potato salad	______
Tea	______	Toast	______
		Date fruitcake	______

Additional Comments: ________________________________

____

____

SECTION III

RESULTS

The chemical analyses of the metabolic diets are presented in table VII. Carbohydrate values were determined by adding the moisture, protein, fat, crude fiber, and ash content of the specific food sample and subtracting this total from the original weight of the sample.

The average protein, carbohydrate, and fat contents of the three metabolic diets as presented in table VII are 115.6 g, 280 g, and 89.3 g, respectively. These values are approximately 11% higher in protein (11 g) and 15% lower in carbohydrate (48 g) than the theoretical values calculated in tables IV, V, and VI. The discrepancy is not due to overestimation of protein as this still leaves 35 g of carbohydrate to be accounted for. It is more likely due to the error in dry weight determination; the dry weights are too low. The average energy obtained by bomb calorimetry of the metabolic diets is 2661 kcal (table IX) which compares favorably with the average theoretical values of 2600 (tables IV-VI) obtained by using the accepted combustion values of 4.3, 4.0, and 9.5 for protein, carbohydrate, and fat, respectively (33). The difference of 61 kcal may be due to an underestimation of protein in the theoretical calculations; 11.0 g of protein is equivalent to 47 kcal. The discrepancy in carbohydrate is therefore due to the inherent error in dry weight determinations and the error in subtracting two large numbers in order to obtain a small one.

The data on energy utilization are presented in table IX. Digestible energy is intake energy minus undigested energy in feces. This represents the energy available for metabolism. The digestible energy excreted in the urine is the actual energy metabolized. There are no significant changes in the prechamber, chamber, and postchamber periods. A high degree of available energy is evidenced by the combined subject average coefficient of apparent *digestibility* of 94%. Of 2508 kcal of digestible energy, 2390 kcal were metabolized indicating a high degree (95%) of energy utilized. This compares favorably with the values obtained for the matched fresh food diet (3).

Food acceptability data are presented in tables X through XII and summarized in table XIII. *Individual diet acceptability is close (range 7.8 to 8.0) to the combined* average value of 7.9. This value is slightly higher than that for a fresh food diet (7.2) served at room temperature (3). The ratings of the four meals were 7.7, 7.9, 8.1, and 7.9 for meals A, B, C, and D, respectively. The differences are too small to be significant. The food items which the average of the subject's combined assessments rated as less than 7 were pineapple cubes, apricot pudding, bacon and egg bites, and apricot cubes. However, it was subject 21 whose consistent low ratings caused the combined averages to fall below 7.

TABLE IX

ENERGY BALANCE AND DIGESTIBILITY

Condition	Subject No.	Total Intake kcal/ 24hr	Undigested in feces kcal/24hr	Digestible kcal/24hr	Excreted in urine kcal/ 24hr	Metabo- lizable kcal/ 24hr	Coefficient of apparent digestibility %
Prechamber	21	2660	214	2447	112	2335	92.0
	22	2660	149	2512	104	2408	94.4
	23	2660	117	2544	117	2427	95.6
	24	2660	137	2524	140	2384	94.9
Chamber	21	2660	165	2496	118	2378	93.8
	22	2660	146	2515	110	2405	94.5
	23	2660	121	2540	115	2425	95.5
	24	2660	197	2464	121	2343	92.6
Postchamber	21	2660	159	2502	139	2363	94.0
	22	2660	147	2514	102	2412	94.5
	23	2660	129	2532	111	2421	95.2
	24	2660	177	2484	124	2360	93.3
				Condition Averages			
Prechamber		2660	154	2507	118	2389	94.2
Chamber		2660	142	2519	116	2403	94.7
Postchamber		2660	153	2508	119	2389	94.3
				Subject Averages			
	21	2660	179	2482	123	2359	93.3
	22	2660	147	2514	105	2409	94.5
	23	2660	122	2539	114	2425	95.4
	24	2660	172	2489	130	2359	93.5
				Combined Subject Averages			
		2660	153	2508	118	2390	94.3

TABLE X

FOOD ACCEPTABILITY OF METABOLIC DIET 1

Food	Subject No.				Combined
	21	22	23	24	Averages
Meal A					
Apricot cereal	4.0	7.8	7.7	8.3	7.0
Apple juice	7.9	8.2	8.9	8.9	8.5
Sausage	5.7	7.6	8.8	8.9	7.8
Cinnamon toast	7.3	8.4	8.7	8.6	8.3
Fruit cocktail	7.1	8.9	8.7	8.5	8.3
Meal B					
Toast bread cubes	7.5	7.5	8.3	6.9	7.6
Chicken and gravy	7.9	7.6	8.9	8.6	8.3
Pineapple cubes	1.4	7.0	8.4	7.7	6.1
Cocoa	7.3	7.3	8.9	8.7	8.1
Meal C					
Toast	7.9	8.4	7.9	7.3	7.9
Tuna salad	8.0	8.8	8.8	8.6	8.6
Apricot pudding	1.1	8.4	8.4	8.4	6.6
Tea	8.1	7.3	8.9	8.7	8.3
Meal D					
Beef and vegetables	7.8	7.9	8.6	8.6	8.2
Orange-grapefruit juice	7.9	8.2	9.0	8.7	8.5
Potato salad	5.9	6.9	7.9	8.6	7.3
Toast	7.9	7.3	7.9	7.3	7.6
Date fruitcake	7.6	6.6	7.6	8.6	7.6

Food acceptability based upon a nine-point scale.

TABLE XI

FOOD ACCEPTABILITY OF METABOLIC DIET 2

Food	Subject No. 21	22	23	24	Combined Averages
Meal A					
Pineapple juice	8.0	8.1	8.9	8.6	8.4
All star cereal	4.5	7.3	7.9	8.6	7.1
Bacon and egg bites	4.4	7.1	7.7	7.3	6.6
Beef sandwich	7.9	6.9	8.4	7.4	7.7
Cocoa	7.2	7.3	8.9	8.6	8.0
Meal B					
Beef bites	7.9	7.4	8.5	7.5	7.8
Potato salad	6.2	6.7	7.7	8.5	7.3
Toast	7.9	7.6	7.5	6.6	7.4
Chocolate pudding	6.5	8.9	8.9	8.6	8.2
Tea	8.0	7.1	8.9	8.7	8.2
Meal C					
Grapefruit juice	7.9	8.7	8.9	8.6	8.5
Chicken bites	8.1	8.4	8.4	7.6	8.1
Potato chip blocks	8.1	8.4	8.1	8.4	8.3
Peaches	7.9	8.9	8.9	8.7	8.6
Brownies	7.9	8.9	7.9	8.7	8.4
Meal D					
Potato soup	8.0	8.6	6.6	6.9	7.5
Shrimp cocktail	8.1	8.7	5.5	6.4	7.2
Toast bread cubes	7.9	8.5	6.0	6.3	7.2
Tea	8.0	7.6	8.9	8.6	8.3

Food acceptability based upon a nine-point scale.

TABLE XII

FOOD ACCEPTABILITY OF METABOLIC DIET 3

Food	Subject No. 21	22	23	24	Combined Averages
Meal A					
Orange-pineapple juice	8.0	8.3	8.9	8.7	8.5
Sugar frosted flakes	4.6	7.4	8.1	8.5	7.2
Bacon squares	7.6	7.4	8.9	8.9	8.2
Peanut butter sandwich	6.4	7.7	7.9	8.1	7.5
Apricot cubes	1.6	7.7	7.4	7.6	6.1
Meal B					
Salmon salad	8.0	8.5	8.7	8.5	8.4
Potato chip blocks	8.0	8.4	8.4	8.4	8.3
Applesauce	7.9	8.8	8.5	8.6	8.5
Pound cake	7.9	8.9	8.4	8.4	8.4
Tea	8.0	7.3	8.9	8.6	8.2
Meal C					
Grape juice	8.0	8.6	8.3	9.0	8.5
Chicken and vegetables	8.0	7.6	7.3	8.5	7.9
Toast	8.0	7.4	7.3	6.9	7.4
Pineapple fruitcake	7.9	6.9	7.9	8.5	7.8
Meal D					
Spaghetti and meat	8.0	6.9	8.9	8.7	8.1
Cheese sandwich	7.8	6.6	7.8	7.6	7.5
Butterscotch pudding	8.2	9.0	9.0	9.0	8.8
Tea	8.0	7.4	8.9	8.6	8.2

Food acceptability based upon a nine-point scale.

TABLE XIII

SUMMARY OF FOOD ACCEPTABILITIES

Meal	Metabolic diet 1	2	3	Average meal acceptability
A	8.0	7.6	7.5	7.7
B	7.5	7.8	8.4	7.9
C	7.9	8.4	7.9	8.1
D	7.8	7.6	8.2	7.9
Average diet acceptability	7.8	7.9	8.0	
Combined diet acceptability		7.9		

Water balance data is presented in table XIV. The average water content of the diets was determined and used to compute intake. Metabolic water was calculated according to Consolazio, et al. (34), taking into consideration the consumption and digestibility of carbohydrate, fat, and protein. The last column indicates the amount of water available as insensible water when body weight is constant. The water requirement per subject consistently decreased with time. Subject 21 had a daily average of 3166 ml in the prechamber period and this decreased to 2230 ml in the post-chamber period. The largest change occurred during the chamber period; the average per man day decreased by 450 ml. The average requirement for water is 2203 ml per man day; however, three subjects averaged 2000 ml and subject 21 averaged 2700 ml. In any event, this average is 334 ml per man day less than that found with a fresh food diet (3). Interestingly enough, the ad lib water and metabolic water requirements of subjects on the fresh food diet and those on the precooked freeze dehydrated foods diet are identical (about 200 ml ad lib and 300 ml metabolic). The entire difference in requirement between the fresh foods and dehydrated foods diets is in the dietary water intake (1544 versus 1200). The amount of water lost through the feces is insignificant. The urinary output was 1130 ml per man day which is 51% of the total water intake. The combined subject average of the difference between intake and output of 1012 ml per man day is higher than one would expect;

the prechamber value of 1311 ml per man day is unusually high and this may reflect an adjustment to the CAF. The chamber and postchamber values of 836 and 861 ml per man day are to be expected. They compare favorably with values of 872 and 839 ml per man day obtained by subjects on a fresh foods diet (3).

Body weight changes are presented in table XV and are tabulated as 3-day weight averages of the initial and final periods for the different experimental conditions. All the subjects lost weight during the prechamber and postchamber periods. Two subjects gained weight during the chamber period which probably reflects decreased physical activity while in the chamber. The greatest weight change, a loss of 2.4 kg was recorded by subject 24 whose initial weight was 86.8 kg.

Body weight changes for the entire 6-week period have been related to nutrient intake as shown in table XVI. The recommended caloric intake for men of this age group engaged in moderate physical activity is approximately 45 kilocalories per day per kilogram of body weight (35). All the subjects except subject 21 had caloric intakes less than this value and therefore their weight losses are to be expected; the 1.1 kg weight loss for subject 21 was not expected in relation to the weight losses exhibited by the other subjects. The recommended protein intake is approximately 1.0 g per day per kilogram of body weight (35). The subjects had 30% to 90% more crude protein in their diet than this recommended value. A linear relationship exists between weight change and caloric intake and protein intake. This relationship holds for all the subjects except subject 21. A composite graph drawn using the data in table XIV and that for a comparable fresh foods diet in which weight loss is plotted versus caloric intake, kilocalories per day per kilogram of body weight shows that subject 21 instead of losing 1.0 kg should have gained more than 2 kg. It would appear that subject 21 is a hypermetabolic individual.

The data resulting from chemical analyses of food and waste products have been utilized in the determination of metabolic balances for organic and inorganic constituents of the diet. These data are presented in tables XVII through XXVI. The data have been normalized to grams per 24 hours and averaged according to the experimental conditions as outlined in table II. The coefficient of apparent digestibility is calculated as the percent net intake (intake minus output in feces) of the actual intake.

Nitrogen balances and digestibilities (table XVII) show the subjects to be in positive balance at all times; there was no difference among the conditions. Subject 21 showed an unusually low digestibility for the prechamber period. The overall digestibility of 91% agrees with that obtained with a matched fresh foods diet (3) and shows that the precooked freeze dehydrated foods diet has a high degree of digestibility. Fat digestibilities show a mean value of 93.6% (table XVIII) which is indicative of a high degree of digestibility. The high degree of digestibility of fiber (table XIX) of 88.5% is an anomaly that may be contingent upon the analytical procedure or other factors as yet not understood. Overall ash digestibility is 87% (table XX). Sodium balance and digestibility are shown in table XXI. Subjects 21 and 24 did not come into positive balance until the chamber period which caused the negative value for prechamber condition averages. The overall balance is slightly positive. Note that the digestibility for subject 21 (prechamber) is significantly lower than all other values. The potassium balances and digestibilities are shown in table XXII. All subjects are in positive balance at all times. Note again the very low digestibility in the prechamber period for subject 21. Calcium balances and digestibilities are shown in table XXIII. All the subjects were in negative balance at all times, by about 0.1 g. The coefficient of apparent digestibility of 14.9% is very low. Diets 1 and 2 were low in calcium and although supplemented to bring the daily intake up to about 0.9 g, the amount added did not take into account the fact that supplementation of calcium by capsule is a very inefficient process due to the low solubility of calcium in the intestinal tract. The added calcium probably was not absorbed (simple calculations show this assumption to be true) and passed out in the feces giving the abnormally low digestibility. This resulted in a daily effective intake of 0.68 g; the amount actually in the diet. This low intake induced a small negative balance. The magnesium digestibility as shown in table XXIV of 53.2% is comparable to that found with a fresh foods diet (3). The phosphorus balances and digestibilities are shown in table XXV. The slight negative balance of 0.07 g and the lower than normal subject average digestibility of 71.5% were probably the result caused by the calcium added to the diet in capsules; at the *p*H of the intestinal tract, calcium and phosphorus form an insoluble compound which is not absorbed. As the calcium becomes unavailable for absorption so does the phosphorus and both pass out of the intestinal tract in the feces. The chloride balance (table XXVI) demonstrates the problem of achieving dietary balance. Note that with time (prechamber, chamber, postchamber), the balance becomes more positive. The prechamber period was only 7 days, and it is obvious that more than 7 days is required to establish a chloride balance; all subjects were in negative balance in the prechamber period. The subjects eventually came into chloride balance as is to be expected.

The summary of physiological measurements is presented in table XXVII. Heart rates, blood pressures, and oral temperatures for all the subjects and for the different conditions were all in the range of normal clinical values.

Summary data of hematological, chemical, and enzyme analyses of blood are presented in tables XXVIII through XXX. The hematological and chemical data show that all subjects maintained a normal clinical status with respect to these measured parameters. Of interest is the fact that the subjects' averages are so close to the combined averages. The distribution of normal values among the general population is far greater than the distribution found among these subjects; this is probably due to the controlled diet and living conditions imposed upon the subjects. The concentration of the blood enzymes as analyzed for all subjects and under all conditions were in the range of normal clinical values. The unusually high SGOT value for subject 22 (prechamber) is probably due to hemolysis; about 80% of whole blood SGOT is in the red blood cell and only 2% is in the serum.

The concentrations of urinary steroids and metabolites for each test condition are shown in table XXXI. Catecholamines, 17-ketosteroids, 17-hydroxycorticoids, creatinine, and creatine are all in the range of normal clinical values for all subjects and during all conditions.

Table XXXII shows the daily defecation patterns of the subjects. These patterns are fairly regular for each subject through the entire 6-week experiment. The fecal weights by collection period and the total and average daily weights are shown in table XXXIII. These data show the individual variation of fecal output even when on a controlled metabolic diet. These data and other data collected in this experiment which pertains to waste management are summarized in table XXXIV. This table shows that food and water intake of 2200 g per man per day will yield 1200 g of urine, 86 g of feces, and 100 g of insensible water (lost to cabin atmosphere). A total solid waste residue (84 g in urine and feces) results from this diet; the waste residue is 20% of the total intake. It should be noted that a net gain each day of 300 ml of water is achieved from the metabolism of 2660 kcal of food.

TABLE XIV

WATER BALANCE

Condition	Subject No.	Average Daily Intake Dietary	Ad lib (ml)	Metabolic	Total	Average Daily Output Urine	Feces (ml)	Total	Balance* difference ml
Prechamber	21	1200	1680	286	3166	1535	158	1693	1473
	22	1200	774	294	2268	848	50	998	1270
	23	1200	918	297	2415	1138	40	1178	1237
	24	1200	913	295	2408	1195	48	1243	1165
Chamber	21	1200	1266	292	2758	1626	58	1684	1074
	22	1200	484	294	1978	888	45	933	1045
	23	1200	316	297	1813	1005	48	1053	760
	24	1200	394	288	1882	1333	83	1416	466
Postchamber	21	1200	738	292	2230	1131	57	1188	1042
	22	1200	326	294	1820	922	35	957	863
	23	1200	286	296	1782	898	48	946	836
	24	1200	512	290	2002	1038	64	1102	900
Condition Averages									
Prechamber		1200	1071	293	2564	1179	74	1253	1311
Chamber		1200	615	293	2108	1213	59	1272	836
Postchamber		1200	416	293	1909	997	51	1048	861
Subject Averages									
	21	1200	1228	290	2718	1431	91	1522	1196
	22	1200	528	294	2022	886	43	929	1093
	23	1200	507	297	2004	1014	45	1059	945
	24	1200	606	291	2097	1189	65	1254	843
Combined Subject Averages									
		1200	710	293	2203	1130	61	1191	1012

* Represents water lost through evaporation via skin and through respiration when body weight does not change.

TABLE XV

BODY WEIGHT CHANGE

Condition	Interval days	Subject No.	Body weight* Initial	Final kg	Change
Prechamber	7	21	60.0	59.2	- 0.8
		22	70.2	69.6	- 0.6
		23	79.9	79.4	- 0.5
		24	86.8	86.0	- 0.8
Chamber	28	21	59.2	59.1	- 0.1
		22	69.6	70.6	+ 1.0
		23	79.4	80.2	+ 0.8
		24	86.0	85.8	- 0.2
Postchamber	7	21	59.1	58.9	- 0.2
		22	70.6	70.1	- 0.5
		23	80.2	79.5	- 0.7
		24	85.8	84.4	- 1.4
		Condition Averages			
Prechamber			74.2	73.6	- 0.7
Chamber			73.6	73.9	+ 0.4
Postchamber			73.9	73.2	- 0.7
		Subject Averages			
		21	60.0	58.9	- 1.1
		22	70.2	70.1	- 0.1
		23	79.9	79.5	- 0.4
		24	86.8	84.4	- 2.4

* Values presented as three-day weight averages.

TABLE XVI

AVERAGE NUTRIENT INTAKE AS RELATED TO BODY WEIGHT

Subject No.	Body weight*			Caloric intake		Protein intake	
	Initial	Final kg	Change	kcal/day	kcal/day/kg body wt**	g/day	g/day/kg body wt**
21	60.0	58.9	- 1.1	2660	44.3	116	1.93
22	70.2	70.1	- 0.1	2660	37.9	116	1.65
23	79.9	79.5	- 0.4	2660	33.3	116	1.45
24	86.8	84.4	- 2.4	2660	30.6	116	1.34

* Values presented as three-day weight averages.

** Based upon initial body weight.

TABLE XVII

NITROGEN BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion g/24hr			Balance g/24hr	Coefficient of apparent digestibility %
			Feces	Urine	Total		
Prechamber	21	18.51	2.89	13.28	16.17	2.34	84.4
	22	18.51	1.52	10.73	12.25	6.26	91.8
	23	18.51	1.29	13.58	14.87	3.64	93.0
	24	18.51	1.21	14.88	16.09	2.42	93.5
Chamber	21	18.51	1.64	12.70	14.34	4.17	91.1
	22	18.51	1.34	10.87	12.21	6.30	92.8
	23	18.51	1.49	11.88	13.37	5.14	92.0
	24	18.51	1.82	12.74	14.56	3.95	90.3
Postchamber	21	18.51	1.84	12.38	14.22	4.29	90.1
	22	18.51	1.30	14.63	15.93	2.58	93.0
	23	18.51	1.71	10.35	12.06	6.46	90.8
	24	18.51	1.45	13.13	14.58	3.93	92.2
			Condition Averages				
Prechamber		18.51	1.73	13.12	14.85	3.66	90.1
Chamber		18.51	1.57	12.05	13.62	4.89	91.5
Postchamber		18.51	1.58	12.62	14.20	4.31	91.5
			Subject Averages				
	21	18.51	2.12	12.79	14.91	3.60	88.5
	22	18.51	1.39	12.08	13.47	5.04	92.5
	23	18.51	1.50	11.94	13.44	5.07	91.9
	24	18.51	1.49	13.58	15.07	3.44	92.0
			Combined Subject Averages				
		18.51	1.63	12.60	14.23	4.28	91.2

TABLE XVIII

FAT DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion in feces g/24hr	Coefficient of apparent digestibility %
Prechamber	21	89.51	7.03	92.1
	22	89.51	5.50	93.9
	23	89.51	2.65	97.0
	24	89.51	4.08	95.4
Chamber	21	89.51	5.50	93.9
	22	89.51	6.63	92.6
	23	89.51	3.95	95.6
	24	89.51	9.26	89.7
Postchamber	21	89.51	5.20	94.2
	22	89.51	7.07	92.1
	23	89.51	3.87	95.7
	24	89.51	7.75	91.3
		<u>Condition Averages</u>		
Prechamber		89.51	4.82	94.6
Chamber		89.51	6.34	92.9
Postchamber		89.51	5.97	93.3
		<u>Subject Averages</u>		
	21	89.51	5.91	93.4
	22	89.51	6.40	92.8
	23	89.51	3.49	96.1
	24	89.51	7.03	92.1
		<u>Combined Subject Averages</u>		
		89.51	5.71	93.6

TABLE XIX

FIBER DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion in feces g/24hr	Coefficient of apparent digestibility %
Prechamber	21	13.95	3.2	77.1
	22	13.95	2.8	79.9
	23	13.95	0.5	96.4
	24	13.95	1.2	91.4
Chamber	21	13.95	1.9	86.4
	22	13.95	2.4	82.8
	23	13.95	0.6	95.7
Postchamber	24	13.95	1.1	92.1
	21	13.95	0.8	94.3
	22	13.95	2.2	84.2
	23	13.95	0.5	96.4
	24	13.95	1.5	89.2
		Condition Averages		
Prechamber		13.95	1.9	86.4
Chamber		13.95	1.5	89.2
Postchamber		13.95	1.3	90.7
		Subject Averages		
	21	13.95	2.0	85.7
	22	13.95	2.5	82.1
	23	13.95	0.5	96.4
	24	13.95	1.3	90.7
		Combined Subject Averages		
		13.95	1.6	88.5

TABLE XX

ASH DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion in feces g/24hr	Coefficient of apparent digestibility %
Prechamber	21	27.60	4.9	82.2
	22	27.60	3.3	88.0
	23	27.60	3.2	88.4
	24	27.60	2.8	89.9
Chamber	21	27.60	3.0	89.1
	22	27.60	2.6	90.6
	23	27.60	2.8	89.9
	24	27.60	4.0	85.5
Postchamber	21	27.60	3.4	87.7
	22	27.60	2.7	90.2
	23	27.60	3.6	87.0
	24	27.60	6.3	77.2
		Condition Averages		
Prechamber		27.60	3.6	87.0
Chamber		27.60	3.1	88.8
Postchamber		27.60	4.0	85.5
		Subject Averages		
	21	27.60	3.8	86.2
	22	27.60	2.9	89.5
	23	27.60	3.2	88.4
	24	27.60	4.4	84.1
		Combined Subject Averages		
		27.60	3.6	87.0

TABLE XXI

SODIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24hr	Excretion Feces g/24hr	Excretion Urine g/24hr	Excretion Total g/24hr	Balance g/24hr	Coefficient of apparent digestibility %
Prechamber	21	4.484	0.289	4.70	4.989	- 0.505	93.6
	22	4.484	0.017	4.32	4.337	0.147	99.6
	23	4.484	0.010	4.18	4.190	0.294	99.8
	24	4.484	0.053	5.07	5.123	- 0.639	98.8
Chamber	21	4.484	0.036	4.17	4.206	0.278	99.2
	22	4.484	0.020	3.83	3.850	0.634	99.6
	23	4.484	0.010	4.55	4.560	- 0.076	99.8
	24	4.484	0.128	4.27	4.398	0.086	97.1
Postchamber	21	4.484	0.028	4.33	4.358	0.126	99.4
	22	4.484	0.017	4.15	4.167	0.317	99.6
	23	4.484	0.014	4.23	4.244	0.240	99.7
	24	4.484	0.091	4.25	4.341	0.143	98.0
			Condition Averages				
Prechamber		4.484	0.095	4.57	4.665	- 0.181	97.9
Chamber		4.484	0.049	4.21	4.259	0.225	98.9
Postchamber		4.484	0.038	4.24	4.278	0.206	99.2
			Subject Averages				
	21	4.484	0.117	4.40	4.517	0.033	97.4
	22	4.484	0.018	4.10	4.118	0.366	99.6
	23	4.484	0.011	4.32	4.331	0.153	99.8
	24	4.484	0.091	4.53	4.621	- 0.137	98.0
			Combined Subject Averages				
		4.484	0.060	4.34	4.400	0.084	98.7

TABLE XXII

POTASSIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24 hr	Excretion g/24 hr: Feces	Excretion g/24 hr: Urine	Excretion g/24 hr: Total	Balance g/24 hr	Coefficient of apparent digestibility %
Prechamber	21	3.473	0.705	2.63	3.335	0.138	79.7
	22	3.473	0.298	2.32	2.618	0.855	91.4
	23	3.473	0.311	3.00	3.311	0.162	91.0
	24	3.473	0.313	3.07	3.383	0.090	91.0
Chamber	21	3.473	0.404	2.51	2.914	0.559	88.4
	22	3.473	0.269	2.29	2.559	0.914	92.3
	23	3.473	0.299	2.59	2.889	0.584	91.4
	24	3.473	0.449	2.66	3.109	0.364	87.1
Postchamber	21	3.473	0.431	2.58	3.011	0.462	87.6
	22	3.473	0.256	2.52	2.776	0.697	92.6
	23	3.473	0.342	2.37	2.712	0.761	90.2
	24	3.473	0.346	2.62	2.966	0.507	90.0
			Condition Average				
Prechamber		3.473	0.407	2.76	3.167	0.306	88.3
Chamber		3.473	0.355	2.51	2.856	0.608	89.8
Postchamber		3.473	0.344	2.52	2.864	0.609	90.1
			Subject Averages				
	21	3.473	0.513	2.57	3.083	0.390	85.2
	22	3.473	0.274	2.38	2.654	0.819	92.1
	23	3.473	0.317	2.65	2.967	0.506	90.9
	24	3.473	0.369	2.78	3.149	0.324	89.4
			Combined Subject Averages				
		3.473	0.368	2.60	2.968	0.505	89.4

TABLE XXIII

CALCIUM BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24 hr	Excretion g/24 hr			Balance g/24 hr	Coefficient of apparent digestibility %
			Feces	Urine	Total		
Prechamber	21	0.888	0.792	0.218	1.010	- 0.122	10.8
	22	0.888	0.716	0.227	0.943	- 0.055	19.4
	23	0.888	0.844	0.253	1.097	- 0.209	5.0
	24	0.888	0.615	0.305	0.920	- 0.032	30.7
Chamber	21	0.888	0.727	0.291	1.018	- 0.130	18.1
	22	0.888	0.665	0.237	0.902	- 0.014	25.1
	23	0.888	0.718	0.253	0.971	- 0.083	19.1
	24	0.888	0.892	0.249	1.141	- 0.253	
Postchamber	21	0.888	0.806	0.253	1.059	- 0.171	9.2
	22	0.888	0.667	0.233	0.900	- 0.012	24.9
	23	0.888	0.935	0.217	1.152	- 0.264	
	24	0.888	0.694	0.220	0.914	- 0.026	21.9
			Condition Averages				
Prechamber		0.888	0.742	0.251	0.993	- 0.105	16.4
Chamber		0.888	0.751	0.258	1.009	- 0.121	15.4
Postchamber		0.888	0.776	0.231	1.007	- 0.119	12.6
			Subject Averages				
	21	0.888	0.775	0.254	1.029	- 0.141	12.7
	22	0.888	0.683	0.232	0.915	- 0.027	23.1
	23	0.888	0.832	0.241	1.073	- 0.185	6.3
	24	0.888	0.734	0.258	0.992	- 0.104	17.3
			Combined Subject Averages				
		0.888	0.756	0.246	1.002	- 0.114	14.9

TABLE XXIV

MAGNESIUM DIGESTIBILITY

Condition	Subject No.	Intake g/24 hr	Excretion in feces g/24 hr	Coefficient of apparent digestibility %
Prechamber	21	0.310	0.139	55.2
	22	0.310	0.177	42.9
	23	0.310	0.112	63.9
	24	0.310	0.160	48.4
Chamber	21	0.310	0.095	69.4
	22	0.310	0.144	53.5
	23	0.310	0.109	64.8
	24	0.310	0.215	30.6
Postchamber	21	0.310	0.120	61.3
	22	0.310	0.148	52.3
	23	0.310	0.140	54.8
	24	0.310	0.184	40.6
		Condition Averages		
Prechamber		0.310	0.147	52.6
Chamber		0.310	0.141	54.5
Postchamber		0.310	0.148	52.3
		Subject Averages		
	21	0.310	0.118	61.9
	22	0.310	0.156	49.7
	23	0.310	0.120	61.3
	24	0.310	0.186	40.0
		Condition Subject Averages		
		0.310	0.145	53.2

TABLE XXV

PHOSPHORUS BALANCE AND DIGESTIBILITY

Condition	Subject No.	Intake g/24 hr	Excretion Feces	Excretion Urine g/24 hr	Excretion Total	Balance g/24 hr	Coefficient of apparent digestibility %
Prechamber	21	1.487	0.453	1.215	1.668	- 0.181	69.5
	22	1.487	0.395	0.933	1.328	0.159	73.4
	23	1.487	0.428	1.171	1.599	- 0.112	71.2
	24	1.487	0.372	1.210	1.582	- 0.095	75.0
Chamber	21	1.487	0.392	1.075	1.467	0.020	73.6
	22	1.487	0.361	0.960	1.321	0.166	75.7
	23	1.487	0.395	1.017	1.412	0.075	72.6
	24	1.487	0.527	1.159	1.686	- 0.199	64.6
Postchamber	21	1.487	0.427	1.018	1.445	0.042	71.3
	22	1.487	0.367	1.133	1.500	- 0.013	75.3
	23	1.487	0.548	0.765	1.313	0.174	63.1
	24	1.487	0.423	1.138	1.561	- 0.074	71.6
			Condition Averages				
Prechamber		1.487	0.412	1.132	1.544	- 0.057	72.3
Chamber		1.487	0.419	1.053	1.472	0.015	71.8
Postchamber		1.487	0.441	1.455	1.896	- 0.409	70.3
			Subject Averages				
	21	1.487	0.424	1.103	1.527	- 0.040	71.5
	22	1.487	0.374	1.009	1.383	0.104	74.8
	23	1.487	0.457	0.984	1.441	0.046	69.3
	24	1.487	0.441	1.169	1.610	- 0.123	70.3
			Combined Subject Averages				
		1.487	0.424	1.129	1.553	- 0.066	71.5

TABLE XXVI

CHLORIDE BALANCE

Condition	Subject No.	Intake g/24hr	Excretion in urine g/24hr	Balance g/24hr
Prechamber	21	10.88	11.80	- 0.92
	22	10.88	11.51	- 0.63
	23	10.88	11.11	- 0.23
	24	10.88	13.04	- 2.16
Chamber	21	10.88	11.37	- 0.49
	22	10.88	9.94	0.94
	23	10.88	11.62	- 0.74
	24	10.88	10.85	0.03
Postchamber	21	10.88	9.95	0.93
	22	10.88	10.32	0.56
	23	10.88	10.00	0.88
	24	10.88	10.92	- 0.04
		Condition Averages		
Prechamber		10.88	11.87	- 0.99
Chamber		10.88	10.95	- 0.07
Postchamber		10.88	10.30	0.58
		Subject Averages		
	21	10.88	11.04	- 0.16
	22	10.88	10.59	0.29
	23	10.88	10.91	- 0.03
	24	10.88	10.60	0.28
		Combined Subject Averages		
		10.88	10.89	- 0.01

Chloride expressed as sodium chloride.

TABLE XXVII

SUMMARY OF PHYSIOLOGICAL MEASUREMENTS

Condition	Heart Rate - 0730-0815 hours			
	Subject No.			
	21	22	23	24
	beats/minute			
Prechamber	66	70	67	75
Chamber	72	71	74	79
Postchamber	82	72	70	74
	Blood Pressure			
	Systolic/Diastolic			
Prechamber	119/81	129/71	113/75	116/75
Chamber	115/78	120/72	120/73	116/76
Prechamber	114/77	124/74	117/69	118/78
	Oral Temperature			
	°F			
Prechamber	96.3	97.4	95.3	96.8
Chamber	97.3	97.0	96.3	96.6
Postchamber	97.8	97.4	96.2	96.4

TABLE XXVIII

SUMMARY OF HEMATOLOGICAL ANALYSES ON BLOOD

Constituent*	Units	Mean ± Standard deviation Subject No. 21	22	23	24	Combined average
White blood cells	mm^3	8167	7028	7316	5944	7114
	±	609	672	760	745	
Red blood cells	$mm^3 \times 10^6$	5.33	4.52	5.40	5.22	5.12
	±	0.33	0.29	0.23	0.37	
Total eosinophils	mm^3	136	157	191	94	145
	±	14	30	32	10	
Segmented neutrophils	mm^3	4726	3999	4553	3510	4197
	±	438	443	578	454	
Lymphocytes	mm^3	3224	2797	3196	2330	2887
	±	413	453	269	416	
Monocytes	mm^3	122	127	141	111	125
	±	32	37	39	24	
Hematocrit	vol%	46	39	46	45	44
	±	3	2	0	1	
Hemoglobin	g%	17.6	14.5	16.5	16.6	16.3
	±	0.3	0.7	0.2	0.4	
Platelets	$mm^3 \times 10^5$	2.68	2.60	2.68	2.66	2.66
	±	0.12	0.19	0.10	0.13	
Reticulocytes	$mm^3 \times 10^4$	7.17	6.70	8.48	6.30	7.17
	±	0.86	0.91	1.05	0.15	

* Segmented neutrophils, lymphocytes, and monocytes determined as percent cells in Schilling differential blood examination. Reticulocytes determined as percent cells and recalculated as cubic millimeters in respect to red blood cell count.

TABLE XXIX

SUMMARY OF CHEMICAL ANALYSIS ON BLOOD

Constituent	Units	Mean ● Standard deviation Subject No.				Combined average
		21	22	23	24	
Glucose	mg %	79	81	80	79	79.8
	±	3	3	6	3	
Total protein	g %	7.4	7.4	7.4	7.4	7.4
	±	0.5	0.2	0.2	0.3	
Albumin	g %	5.2	4.9	4.9	5.0	5.0
	±	0.3	0.3	0.2	0.2	
A/G Ratio		2.3	1.9	2.0	2.1	2.1
	●	0.2	0.2	0.2	0.3	
Creatinine	mg %	1.8	1.5	1.7	1.8	1.7
	±	0.2	0.3	0.3	0.2	
Alpha-amino nitrogen	mg %	7.6	8.1	7.9	8.1	7.9
	±	1.2	1.6	0.6	1.7	
Calcium	mg %	10.3	10.4	9.9	10.3	10.2
	●	0.4	0.3	0.5	0.5	
Phosphorus	mg %	3.6	3.6	3.6	3.5	3.6
	±	0.2	0.1	0.2	0.3	
Sodium	mEq/l	141.6	141.1	140.5	141.4	141.2
	±	4.4	3.5	2.8	2.9	
Potassium	mEq/l	4.3	4.6	4.4	4.5	4.5
	±	0.2	0.4	0.3	0.3	
Chloride	mEq/l	103.5	102.4	102.5	102.5	102.7
	±	2.3	0.9	1.6	1.6	

TABLE XXX

BLOOD ENZYMES

Condition	Subject No.	Acid phosphatase	Alkaline phosphatase	SGOT*	SGPT**
Prechamber	21	12.7	41.7	14.5	6.3
	22	11.9	40.0	75.2	
	23	14.4	32.9	18.1	12.3
	24	14.0	26.4	14.7	5.8
Chamber	21	10.5	41.5	13.5	4.6
	22	9.3	31.0	18.9	16.2
	23	11.9	36.9	14.6	6.3
	24	11.6	29.5	13.6	7.3
Postchamber	21	8.7	42.6	9.9	3.5
	22	6.8	29.8	12.1	9.2
	23	9.7	37.2	14.7	10.5
	24	10.1	29.1	16.0	9.6

Values expressed in International units as micromols of substrate converted per minute per liter of serum.

* Serum glutamic oxalacetic transaminase.

** Serum glutamic pyruvic transaminase.

TABLE XXXI

URINARY STEROIDS AND METABOLITES

Condition	Subject No.	Catechol-amines ug/24hr	17-Keto-steroids mg/24hr	17-Hydroxy-corticoids mg/24hr	Creatinine g/24hr	Creatine mg/24hr
Prechamber	21	73.9	11.2	7.8	1.66	107
	22	50.4	4.6	5.5	1.75	127
	23	59.1	22.0	7.8	2.38	87
	24	43.8	17.4	8.8	2.47	133
Chamber	21	77.3	14.1	8.2	1.70	87
	22	70.0*	6.4	7.0	1.73	97
	23	44.1	20.1	8.9	2.36	93
	24	40.0	13.4	7.4	2.35	130
Postchamber	21	67.1	11.9	7.9	1.67	73
	22	46.6	6.6	5.3	1.83	57
	23	48.6	19.7	9.4	2.22	80
	24	40.2	12.8	7.6	2.37	80

* Not significantly different from prechamber or postchamber.

TABLE XXXII

DEFECATION PATTERNS

Day	Subject No. 21	22	23	24
1	XX	X	XX	X
2	X		X	
3	XXX	X	X	X
4	XX	X	X	X
5		X	X	
6	XX	XX	X	XX
7				
8	X			X
9	XX	XX	XX	
10	XXX		X	XX
11		XX		
12	X	XX	X	X
13	X	X	XX	X
14	XX			
15	X	XX	XX	XX
16	XX	XX	X	
17	X	X		
18	X	XX	X	XX
19	X		X	
20	XXX	X	X	X
21	X	X	X	
22	XX	X	XX	
23	X	X	X	
24	X	XX	X	XX
25	X	X	X	X
26	X	X		
27	XX	X	X	X
28	X	X	XX	
29	X		X	
30	X	XX	X	
31		X		X
32	XX	X	X	XX
33	XX	XX	X	
34	X	XX	X	X
35	X	X		X
36	XX	XX	XX	XX
37	XX			
38	X	X	X	
39	X	XX	X	XX
40	X	XX	XX	
41	XX	XX	X	X

TABLE XXXIII

FECAL WEIGHTS

Sample No.	Collection period days	Subject No. 21	22	23	24
		g			
F1	3	587.5	150.5	197.7	119.1
F2	3	516.6	302.5	161.4	310.2
F3	6	718.4	441.0	476.7	364.1
F4	8	760.3	468.2	494.6	625.4
F5	6	605.1	513.2	450.1	802.9
F6	8	677.0	671.6	586.3	1112.4
F7	3	361.6	107.0	174.8	11.3
F8	3	180.0	275.4	151.3	570.0
Total net weight (40 days)		4407	2929	2693	3915
Average daily weight		110	73	67	98

TABLE XXXIV

WASTE MANAGEMENT

	Input	Output
Water, ml/man day		
Food	1200	
Ad libitum	700	
Metabolic	300	
Urine		1140
Feces		60
Lost to cabin atmosphere (by difference)*		1000
	2200	2200
Solids, dry weight, g/man day		
Food	520	
Urine		58
Feces		26
	520	84

* Balance assumes no change in weight.

DISCUSSION

All four subjects completed the 6-week experimental study, which included 28 days within the LSSE and a portion of the time dressed in an unpressurized MA-10 pressure suit. There were no apparent adverse effects due to the physical, psychological, or dietary stresses enforced upon them. For all practical purposes, the results obtained in this experiment, during which time the subjects ate an experimental diet prepared from precooked freeze dehydrated foods, and a comparable experiment (3) during which four subjects ate a matching fresh food diet, are identical. In all the experiments completed in this series thus far, the subjects were maintained clinically within the normal range of values reported for healthy individuals as determined from biochemical and physiological measurements. The narrow limits within which the clinical data varied is a reflection of the excellent dietary control effected during these studies. Since the results obtained with the fresh food diet (3) and other experiments are essentially identical, any generalizations (12) to be made apply to all experiments.

The daily energy and crude protein in these diets can maintain a 70 kg man in the LSSE at a constant weight; 38 kcal per kilogram of body weight per day and 1.65 g of protein per kilogram of body weight per day in the diet is required to maintain body weight under these experimental conditions. The subjects were in nitrogen and electrolyte balance. All the digestibilities were high and show good utilization of major foodstuffs and mineral elements. Two of the three precooked freeze dehydrated food diets served were deficient in calcium. The amount of calcium that was added to the diet, in capsules, was insufficient to prevent a very slight but negative calcium and phosphorus balance in the subjects. For the period of this experiment, the slight negative balance was of no real consequence with respect to general health.

As pointed out before (3), the extraordinarily high apparent digestibility of fiber is enigmatic. It may be due to a chemical modification of the fiber in the stomach and intestine that alters its solubility and produces all analytical or methodological disappearance which is then calculated as digestibility. Or, the microflora in the intestines may degrade fiber, utilize it, and cause an apparent digestibility. Finally, the microflora may degrade cellulose to smaller units which can be further degraded by intestinal enzymes to provide glucose: in this instance cellulose would be available for tissue utilization. The possibility that the microflora in the intestinal tract may modify cellulose should be given serious consideration. For example, Bacteroides fragilis, presumably the prominent bacterium in the lower intestinal tract of man (37), has been found to split dextran (38), and a strain of pleomorphic Bacteroides isolated from human feces produced heparinase and could dissimilate heparin and related mucopolysaccharides (39). However, the fiber content of the diet is too small with respect to total carbohydrate to determine this utilization indirectly from the energy balance.

Water balance data are consistent with reported values (40) for individuals at ambient temperatures and pressures and at low levels of physical activity.

Heart rate, blood pressure, and body temperature were within clinically normal ranges. No significant changes were observed among the separate experimental periods.

Confinement in the LSSE did not affect the water, energy, or protein requirements of four subjects over that found under baseline conditions. The precooked freeze dehydrated food diet was adequate although low in calcium, and was efficiently utilized. There were no significant changes in the physiological, biochemical, nutritional, or clinical status of the subjects.

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13. ABSTRACT

A 6-week study with four college students as volunteer subjects was conducted for the purpose of evaluating the water, caloric, and protein requirements of individuals undergoing stresses imposed by simulated aerospace conditions. The subjects were confined in a controlled activity facility for 2 weeks and in the Life Support Systems Evaluator for 4 weeks during which time they wore an unpressurized MA-10 pressure suit 8 hours each day for 14 consecutive days. A 3-day cycle diet of precooked freeze dehydrated foods was served at room temperature and was comprised of about 105 g of protein, 328 g of carbohydrate, 89 g of fat, and 2600 kcal per day. The daily requirement of water was 2200 ml per man day of which 700 ml were consumed ad libitum. The diet was highly acceptable and efficiently utilzed. Only minimal body weight changes were observed. The nutrient intake of the diet was adequate in that a 70 kg man was maintained without any weight loss. Metabolic balances show excellent adjustment to the diet; all subjects were in positive balance for nitrogen and for the major inorganic constituents. All the clinical data including heart rate, blood pressure, and oral temperature were in the normal ranges and no significant differences were observed due to confinement in the Life Support Systems Evaluator. All subjects maintained excellent health throughout all the test periods.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aerospace nutrition						
Biochemical evaluation						
Physiological evaluation						
Metabolic evaluation						
Diets						
Confinement						
Precooked foods						
Frozen foods						
Dehydrated foods						
Bite size foods						
Life support						